(12) UK Patent Application (19) GB (11) 2 337 722 (13) A

(43) Date of A Publication 01.12.1999

(21) Application No 9811538.9

(22) Date of Filing 29.05.1998

(51) INT CL[6]
G21F 5/10

(52) UK CL (Edition Q)
B4Q Q5B

(56) Documents Cited
GB 1456860 A   US 5564498 A

(58) Field of Search
UK CL (Edition P) B4Q, B8P PV
INT CL[6] G21F 5/10 7/015
Online: WPI

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(54) Abstract Title
Dry storage vault

(57) Canisters 400 are stored above ground in separate chambers of a concrete vault. The vault is constructed from pre-cast concrete sections 120, 140, 150. Each chamber has a stainless steel liner 450, defining inner and outer annular spaces 510, 520 between the hot canister wall 402 and the concrete wall 465. Cooling air flows through both spaces 510, 520 by natural convection. Cold air flows in through base level vents 170. Hot air from the outer annular spaces discharges through upper vents 172 formed in the concrete and that from the inner space discharges through a gap 436 between a metal lid 430 and flanges 432, 434. Slots 532 are formed between inner and outer annular spaces to allow discharge of all hot air even if one vent is to become blocked. The concrete walls are cooled by further ducts formed as an integral part of the pre-cast structures.

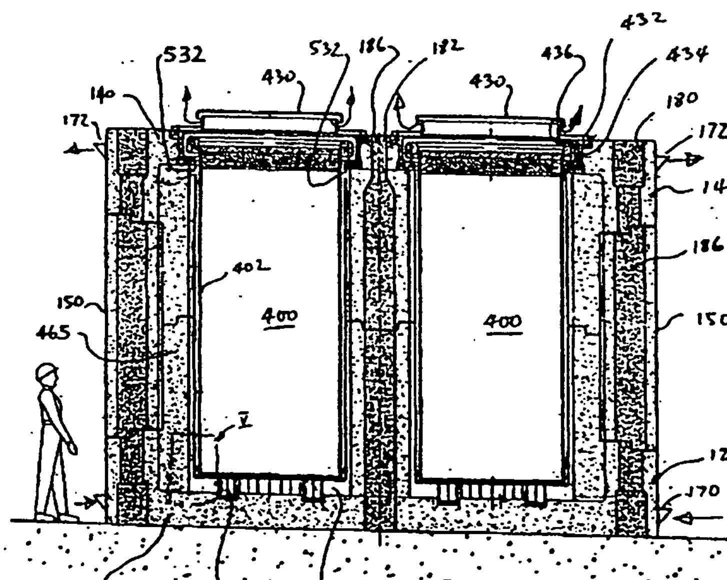


Fig 4

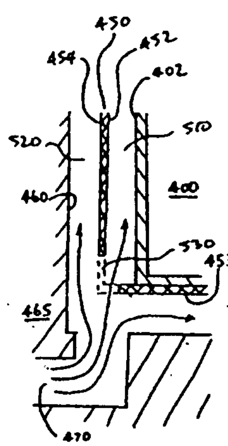
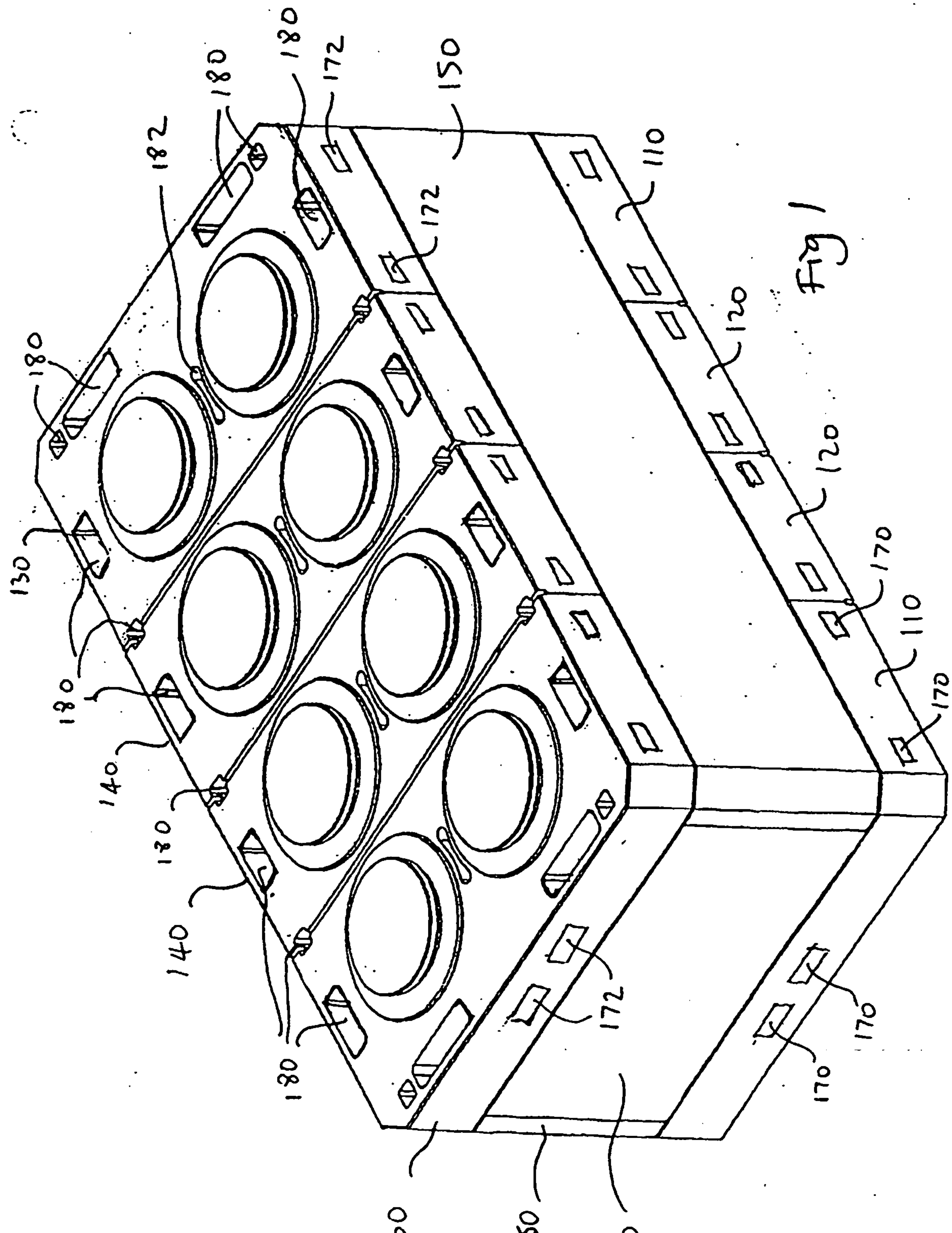


Fig 5

GB 2 337 722 A

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995


180
180
182
172
150
172
110
120
120
120
170
110
170
172
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170
170
180
180
130
180
180
140
130
140
180
130
150
160

Fig 1

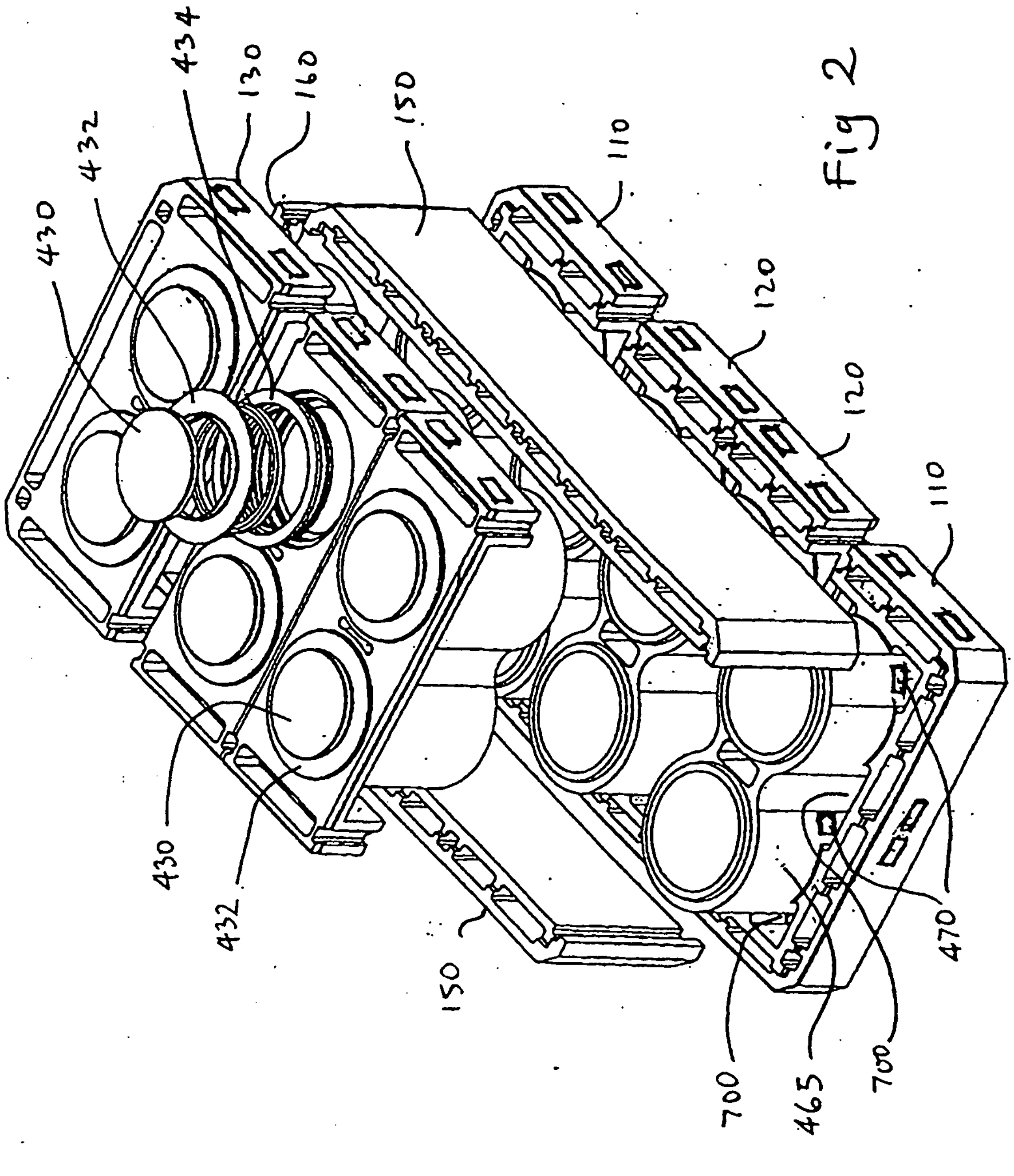
430
432
434
130
160
150
110
120
120
110
430
432
150
700
465
700
470

Fig 2

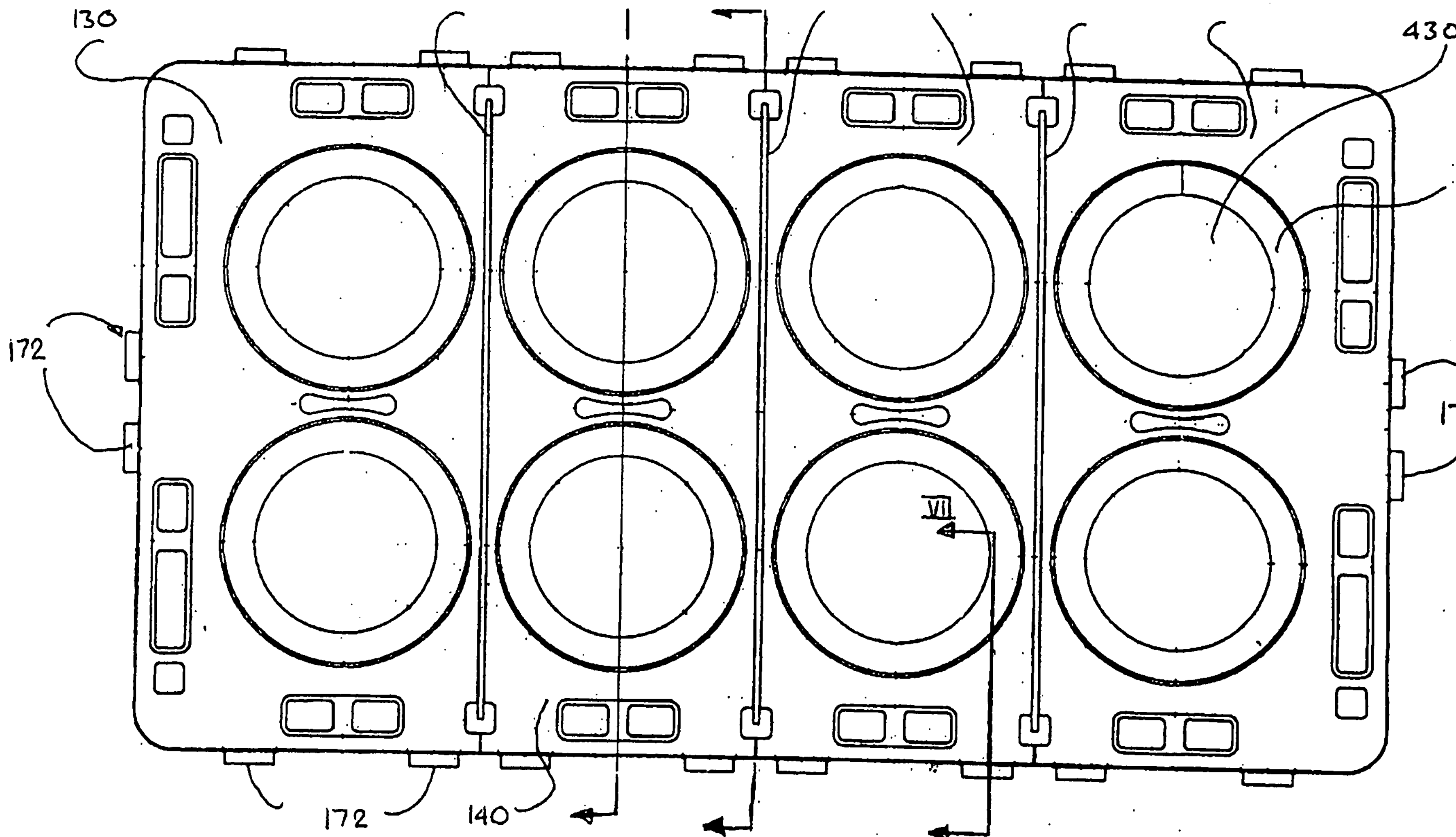

Fig 3

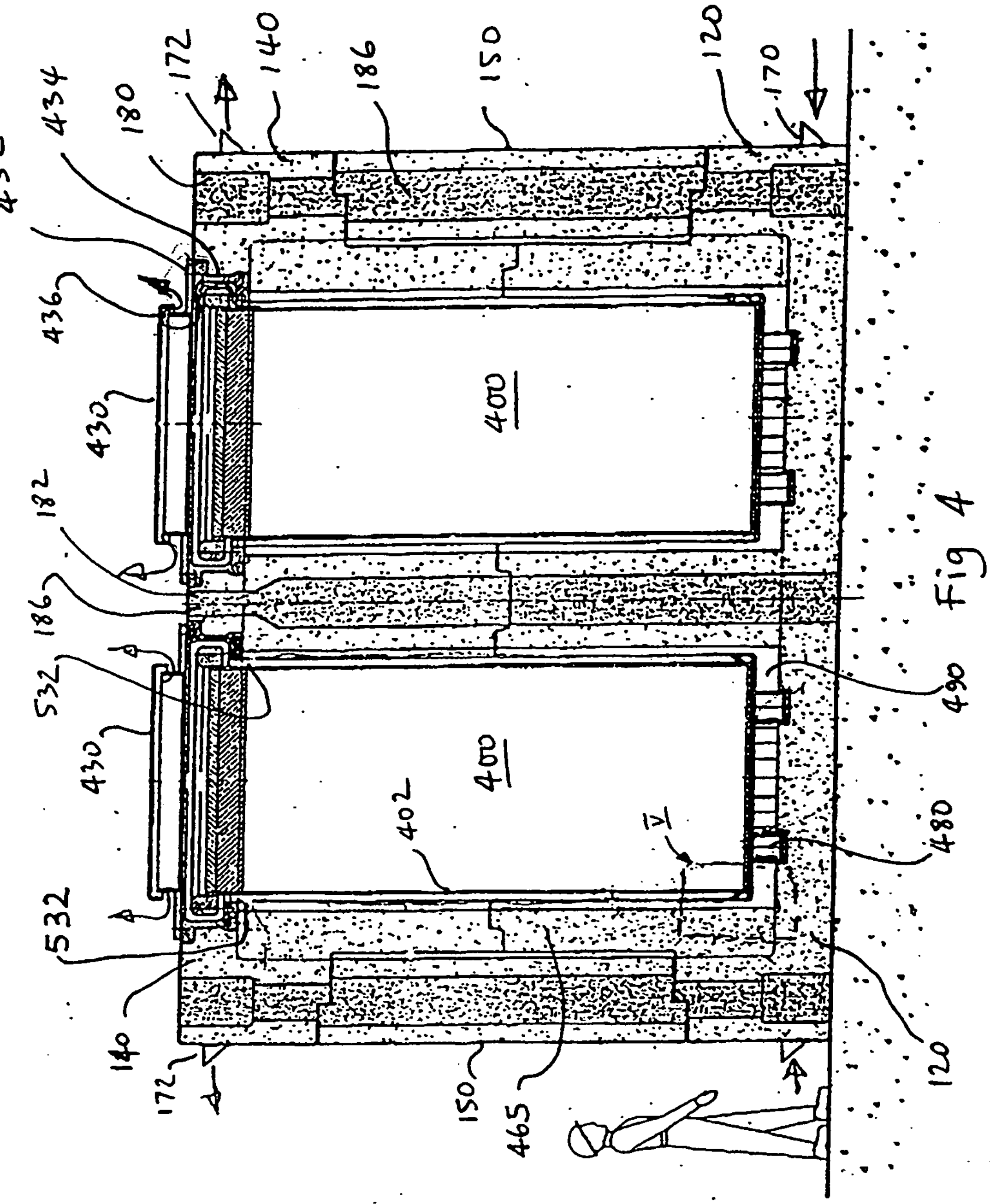
172
140
180
434
432
186
150
120
170
436
430
400
182
186
532
490
402
480
V
532
140
172
150
465
120

Fig 4

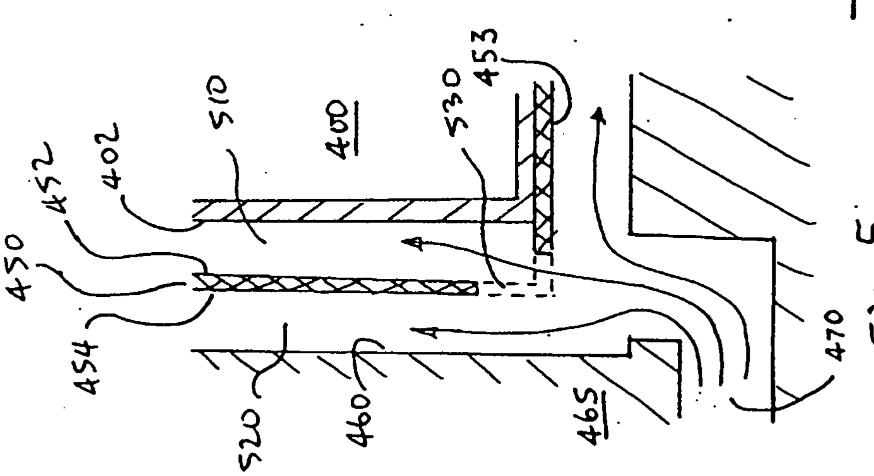
450
452
402
510
400
530
453
454
520
460
465
470

Fig 5

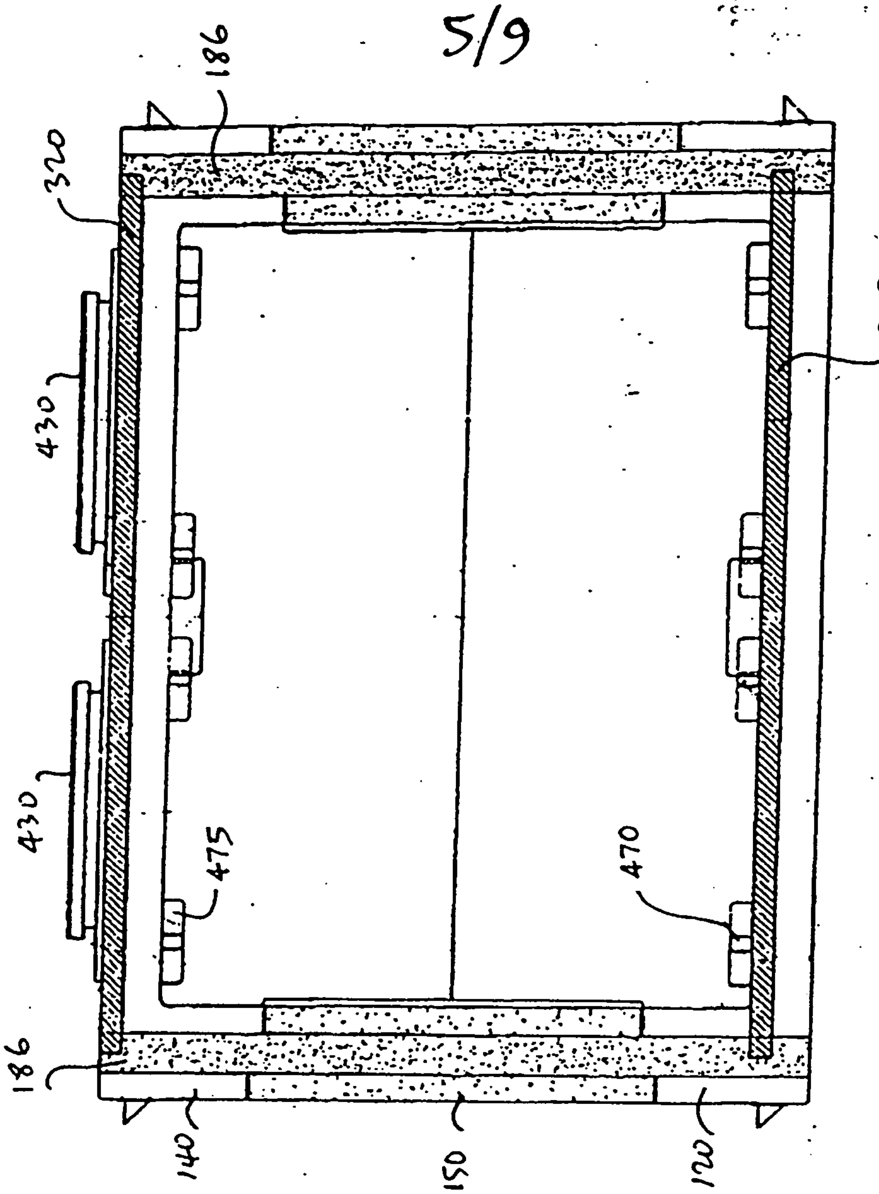
186
320
430
430
475
186
140
150
120
470
310

Fig 6

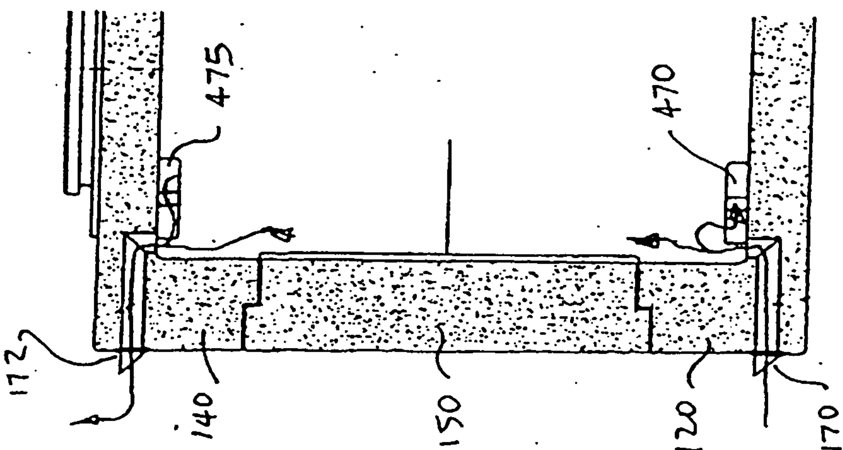
475
470
172
140
150
120
170

Fig 7

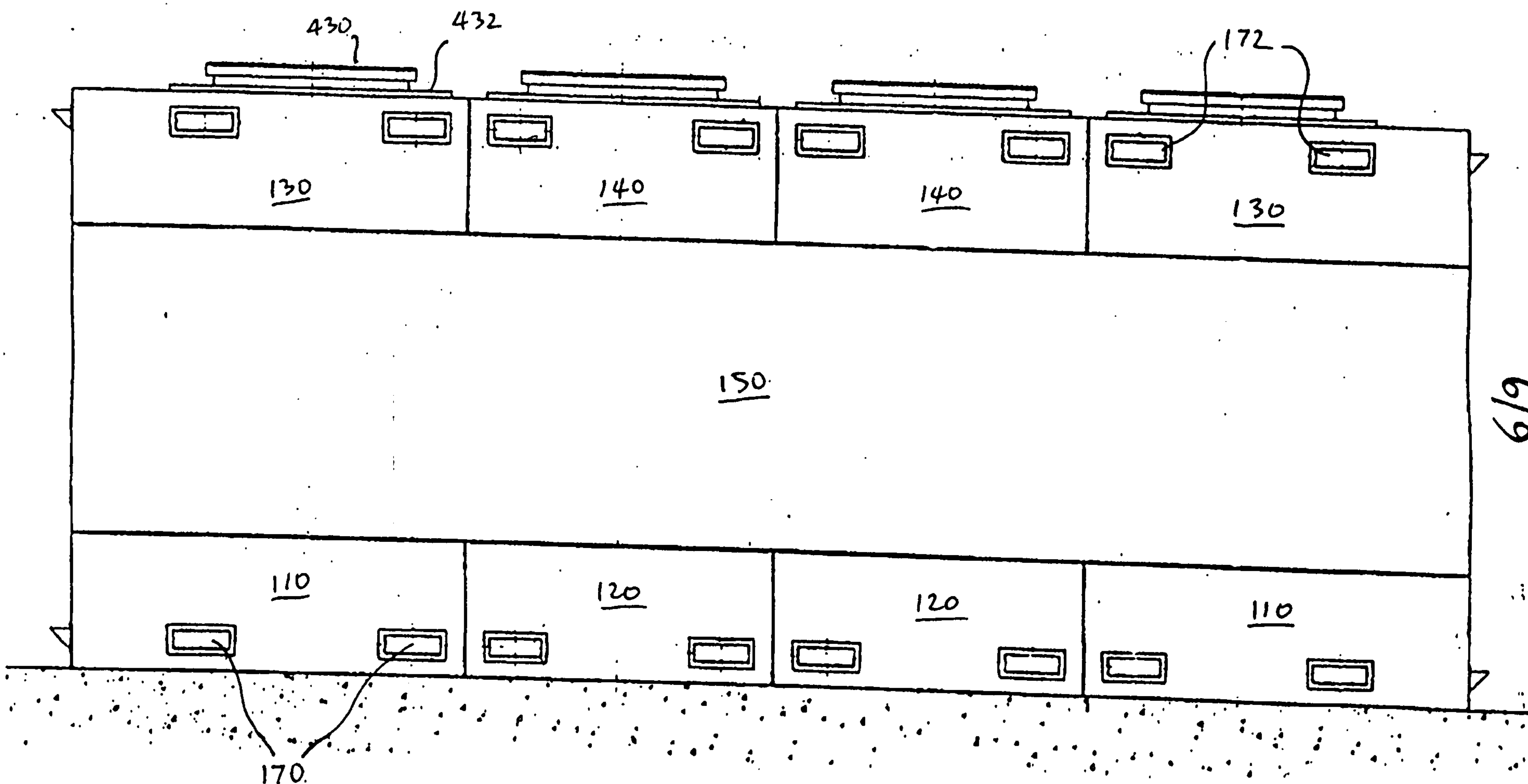

Fig 8

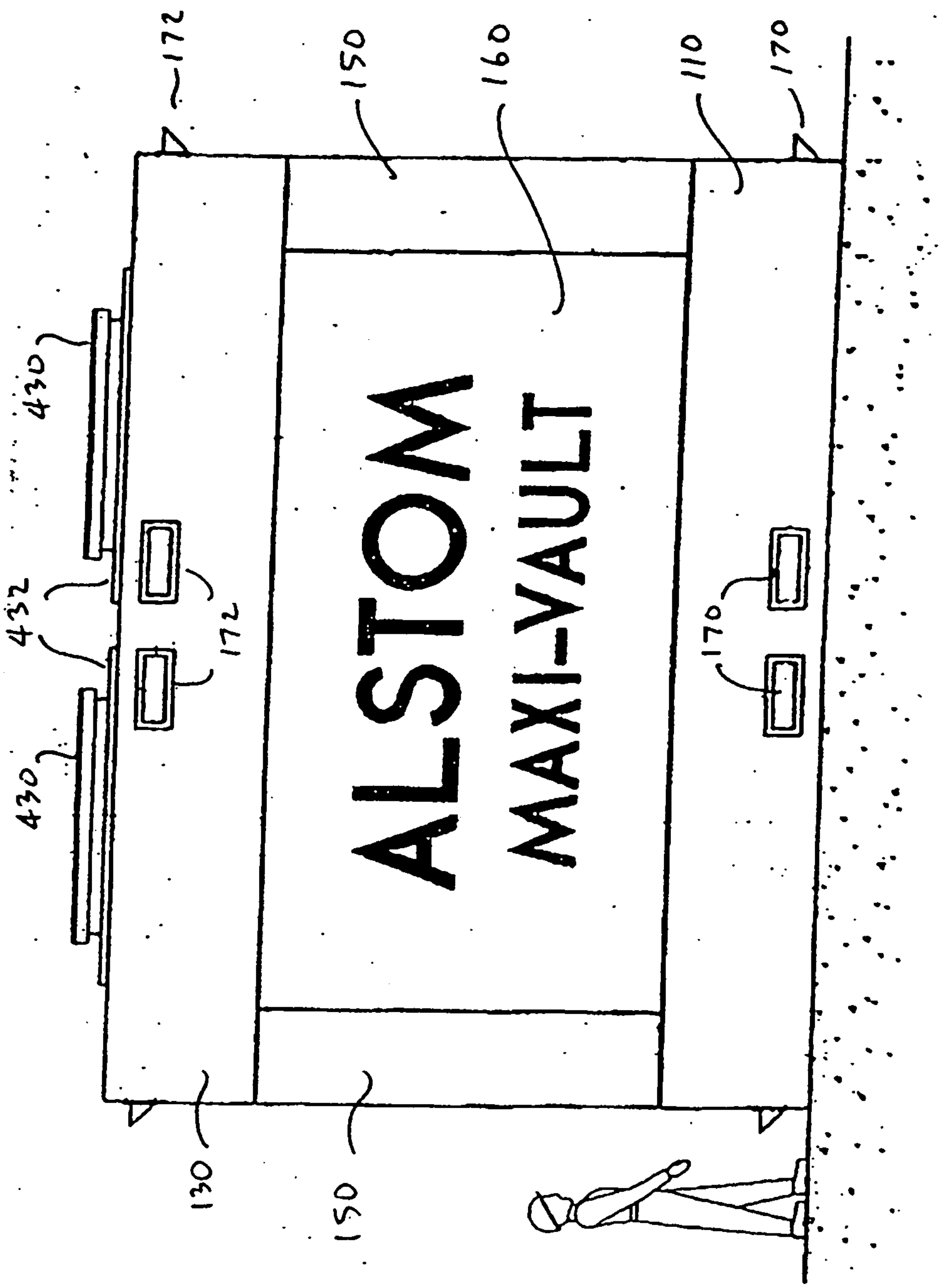
ALSTOM
MAXI-VAULT
172
150
160
110
170
430
432
172
432
172
430
170
170
130
150

Fig 9

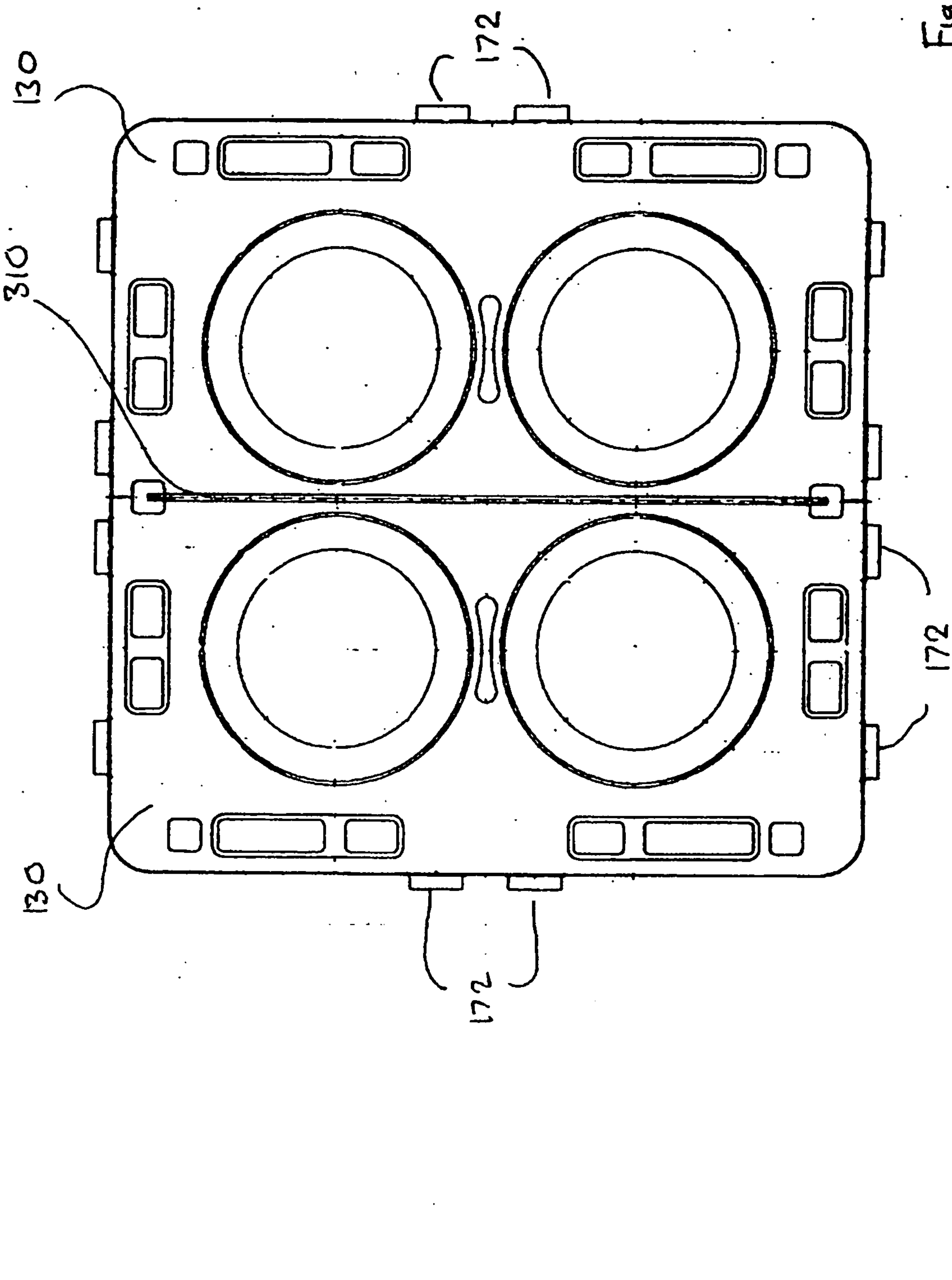

Fig 10

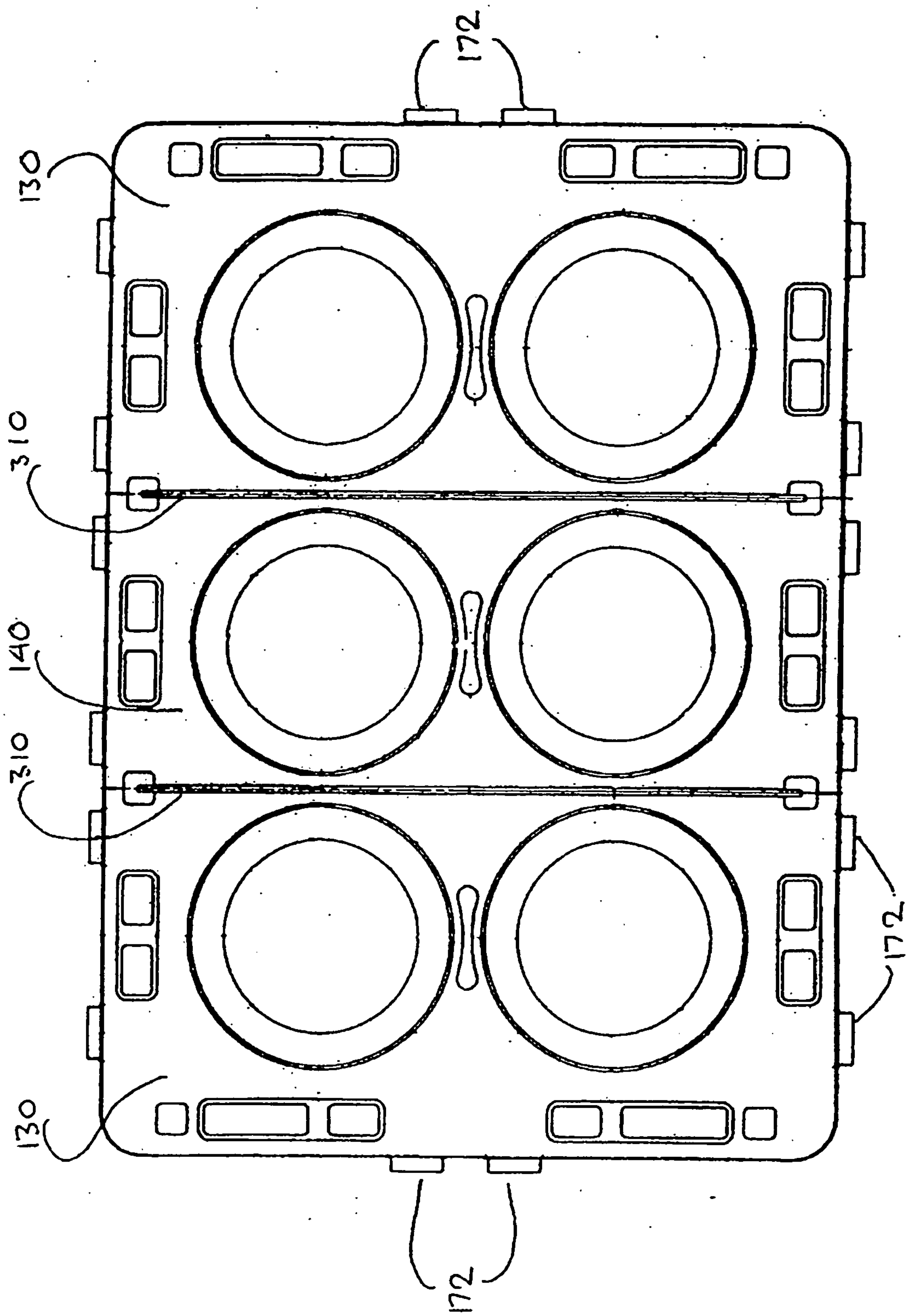

Fig 11

Dry Storage Vault

This invention relates to dry storage vaults. It particularly relates to dry storage vaults for the storage of spent nuclear fuel.

In a known type of dry storage vault, canisters of spent fuel are arranged vertically in a chamber and air is caused to pass horizontally over the canisters by thermosyphon action. The chamber communicate with a flue which draws hot air upwards and causes cool air to be drawn into the chamber. Thus heat is removed by natural convection without the need for auxiliary cooling fans. Such a vault is described in "The developed technology of modular vault dry storage", Nuclear Engineering International April, 1984. While this has proved to be an effective method of dealing with spent fuel, it does have a number of disadvantages. The chamber and flue have to be built on-site to minimize the risk of radiation leakage from the fuel, the construction must be built on site using poured concrete. Suitable foundations must be provided for the resultant massive structure, and all the machinery required for vault construction must be transported to the site where the vault is to be constructed.

The present invention arose from an attempt to provide an improved dry storage vault. The invention provides a dry storage vault for heat-emitting radioactive material contained within a canister, the vault comprising: a concrete body having a chamber to accommodate the canister with its long axis substantially vertical, a cylindrical liner arranged within the chamber to define a first annular space between the inner wall of the

chamber and the outer wall of the liner, the liner being arranged to accommodate the canister therein with a clearance, the clearance defining a second annular space, air inlet means at the lower end of the chamber communicating with the first and second annular spaces at the lower ends thereof, and air outlet means at the upper end of the chamber communicating with the first and second annular spaces at the upper ends thereof.

Unlike the prior art, each canister has its own cooling arrangement. Unlike the prior art, a vault in accordance with the invention does not require the provision of a large building with its attendant massive foundation. It can be assembled from precast units manufactured off site and only requires a suitable hard surface capable of supporting the weight of the vault. The provision of the liner reduces the temperature to which the concrete structural members are subjected, resulting in reduced thermal stresses and reducing the likelihood of degradation of the concrete.

Embodiments of the invention will now be described, by way of non-limiting example only, with reference to the drawings in which:

Fig 1 shows an isometric view of a first embodiment of the invention;

Fig 2 shows an exploded view of fig 1;

Fig 3 shows an exterior plan view of fig 1;

Fig 4 shows a sectioned elevation view of fig 1 on line IV-IV of fig 3;

Fig 5 shows a detail of fig 4 on an enlarged scale;

Fig 6 shows a sectioned view of fig 1 along line VI-VI of fig 3;

Fig 7 shows a scrap view of fig 1 along line VII-VII of fig 3;

Fig 8 shows a side elevation view of fig 1;

Fig 9 shows an end elevation view of fig 1;

Fig 10 shows a second embodiment of the invention; and

Fig 11 shows a third embodiment of the invention.

Referring now to figures 1-9 the vault consists of a number of precast concrete components, namely, end base members 110, centre base members 120, end top members 130, centre top members 140, side wall members 150, and end wall members 160. The vault also comprises a number of cylindrical steel liners 450 whose function will be described later, flange members 432, 434, and lids 430.

Members 110, 120, 130 and 140 have a number of channels which provide ducts for flow of air therethrough when the vault is in its assembled state. The members are

provided with steps which serve both to assist assembly and to provide a tortuous path for radiation to prevent leakage thereof. The members also have channels 180, 182 which, after assembly, are fitted with concrete 186 to secure the units together and provide a monolithic structure.

Referring now to figs 2, 4 and 5, the lower and upper members 110, 130 and 120, 140 have cylindrical bores which, in the assembled vault, constitute chambers in which fuel canisters 400 are accommodated. Each chamber has a wall 460 constituting a concrete surface. Each chamber is provided with a stainless steel liner 450 arranged so as to provide a first annular gap 510 between the fuel canister 400 and the inner surface 452 of the liner 450, and a second annular gap 520 between the outer surface 454 of liner 450 and the concrete wall 460. These annular gaps allow passage of cooling air to flow therethrough as will be described later. As seen in fig 5, the bottom of the cylindrical liner 450 is provided with a number of apertures 530 to allow passage of air therethrough.

The base members 110, 120, have air ducts 170 to allow entry of air from the atmosphere into the interior of the chamber 400 at the base thereof via slots 470 through the lower inner concrete wall 465 of the chamber, and to pass into annular gaps 510, 520.

The top members 130, 140 have ducts 172 to allow air which has flowed via annular gap 520 to pass to the atmosphere via slots 475 through the upper inner concrete wall 465

of the chamber. The openings of ducts 170, 172 have screens to prevent entrance of birds or other animals.

The top of the liner 450 terminates a first steel flange 434 which is sealed to its respective concrete member 410, 420. A second steel flange 432 is fitted over the first flange 434. A steel lid 430 is fitted over the second flange. The lid 406 of the canister 400 locates within but does not touch the first flange 434 so as to provide a labyrinthine passage for hot air. The lid and flange are such to leave a gap 436 through which air which has flowed via annular gap 510 to pass to the atmosphere.

The air at the top of the inner annular gap 510 can reach a temperature which could cause long-term damage to concrete. Hence this very hot air is normally allowed to escape by an air path whose walls are constituted by steel members and thus does not come into direct contact with concrete.

The air at the top of the outer annular gap 520 will not reach a temperature sufficiently high to cause damage to concrete and hence can be allowed to escape via ducts cast into the concrete side members and whose walls consist of the concrete of which the walls are cast. This is also the situation when gap 436 is accidentally blocked.

A number of communication slots 532 in the liner 450 provide communication between the inner and outer annular spaces at the top of the chamber. This provides an alternative non-preferential flow path via annular gap 520 and ducts 172 to atmosphere in the event

that gap 436 is accidentally blocked. The hot air from annular gap 510 is diluted and cooled by mixing with the cooler air flow in annular gap 520.

The base 453 of the liner 450 is supported by spacing members 480 above the base of the chamber to provide a space 482 to allow free passage of air from inlet duct 170 to the entire lower periphery of the liner 450 via slot 470.

As shown in fig 6, bars 310 are located in grooves provided therefor to cover the joins between adjacent base members 110, 120 and top members 130, 140. These bars provide a labyrinthine path to inhibit egress of stray radiation.

The vault is designed to be used in the open air. Having prepared a suitable hard standing, the individual units, which may be fabricated off-site using conventional concrete casting techniques, are assembled. Fuel canisters 400 are then placed in the chambers as required and the flanges 432 and lids 430 fitted. Heat from the fuel in the canisters causes the surface temperature of the outer cylindrical wall 402 of the canister 400 to rise. Part of this heat is carried away by convection by air in annular gap 510, the remainder as radiant heat. This radiant heat falls on liner 450 and causes its temperature to rise. The inner surface 452 is blackened to minimise the radiation of heat back to surface 402.

Some heat is lost from the liner 450 by convection, both from its inner surface 452 by air in inner annular gap 510 and, from its outer surface by air in outer annular gap 520.

The remainder of the heat is lost by radiation from its outer surface 454. The outer surface 454 is a natural stainless steel finish to enhance the surface radiation of heat. This radiant heat warms the concrete surface 460 of the chamber. Some of this heat is absorbed by the concrete by conduction, the remainder is carried away from surface 460 by convection by air in the outer annular gap 520.

Thus the air in both annular gaps 510 and 520 becomes heated and rises. In general, air in gap 510 will rise and leave the chamber via lid 430, while air in gap 520 will leave via the vents 172. As noted above, in the event of a blockage, the communication slots in the liners allow air in gap 510 to leave via vent 172 and air in gap 520 to leave via lid 430.

The heat absorbed by the concrete will cause its temperature to rise. Some of this heat is removed by further ducts 700 cast into the upper and lower members. These ducts communicate with the inlet and outlet ducts 170, 172.

The surface temperature of the canisters 400 will normally be sufficiently high that, in the absence of liner 450, heat radiated from the canister would cause the temperature of the concrete 460 to rise to a level which could give rise to long-term damage of the concrete. Liner 450 prevents the temperature of wall 460 from becoming excessive, both by providing a shield from direct thermal radiation and by increasing the surface area from which heat may be transferred to the air by convection. This reduction in concrete temperature allows conventional concrete to be used without the need for special

strengthening members.

It will be seen that the vault cooling system is driven by the natural buoyancy of heated air, with the stored irradiated fuel providing the source of heat. The cooling system air flow is a function of the decay heat of the stored fuel: the hotter the fuel, the greater the bouyancy of heated air, the faster the air flow, the greater the cooling effect of the air. This arrangement thus provides a self-regulating, inherently reliable, cooling system with diversity of flow paths in the event of accidental blockage.

Loading and loading operations will now be described.

The loading operation starts when the Transfer Cask and canister arrives at the Vault on the back of a tow trailer. The Canister Transfer Cask is removed from the trailer using the overhead crane and lifted onto the vault storage location. The Cover plate from the storage location has been previously removed by the Crane. The shield doors on the base of the transfer cask are opened to permit the canister to be lowered out of the Transfer Cask into the vault storage position by the overhead Crane. The vault shielding integrity is complete by the integral shield plug that is part of the canister lid. The Transfer Cask shield doors are closed and the Transfer Cask removed from the vault. After the vault Cover Plate is replaced the storage transfer operation is complete.

When the canister has to be removed from the Vault it can be placed directly into a transportation cask without having to return to a pool facility. A stand is located adjacent

to the Vault and this is used to support the transport cask in a vertical position ready to receive the canister. An adaptor ring is docked on top of the transport cask to permit it to interface with the Vault transfer cask. The canister is removed from the vault using the overhead Crane and Transfer Cask which is then docked onto the Transportation Cask. The canister can then be transferred directly into the Transport Cask from the Transfer Cask. After the Transfer Cask has been removed, the lid to the Transportation cask is fitted and the Cask loaded onto a trailer for off-site shipment.

While the above embodiment provided storage for eight canisters, the invention can be applied to greater or lesser numbers.

Figure 10 corresponds with fig 3, and shows an arrangement for four canisters. Compared with the first embodiment this uses the same end units 110, 130 and 160 as the first embodiment and only requires the provision of a special side wall in place of the side wall 150.

Figure 11 corresponds with fig 3, and shows an arrangement for use with six canisters. This arrangement uses two sets of end units 110, 130 and end walls 160 and only one set of centre units 120, 140. It only requires the provision of a special side wall in place of side wall 150.

It will be seen that, compared with prior art arrangement, vaults in accordance with the invention can be manufactured off-site in prefabricated form, only requiring assembly

on site.

It also makes it possible to construct a range of vaults of different sizes using a number of components common to all designs, only a minimal number of components being peculiar to the particular design.

A number of modification are possible within the scope of the invention.

Although in the described embodiments the flanges and cap are steel, any other suitable material, metal or non-metal, may be used. It is only necessary that the materials be capable of withstanding relatively high temperatures and low levels of neutron radiation without deterioration, and provide adequate radiation shielding.

The vault may be used to store any suitable heat-emitting radioactive material in canisters, whether spent nuclear fuel or high level waste, and is not peculiar to any one type of material.

If the installation is such that it can be ensured that the exit vents for hot air cannot become blocked, the communication slots at the top of the chamber affording communication between the inner and outer annular spaces may be omitted. This will ensure that the hotter air from the inner annular chamber never come into contact with concrete at all.

CLAIMS:

1. A dry storage vault for heat-emitting radioactive material disposed within a canister, the vault comprising

a concrete body having a chamber to accommodate the canister with its long axis substantially vertical,

a cylindrical liner arranged within the chamber to define a first annular space between the inner wall of the chamber and the outer wall of the liner,

the liner being arranged to accommodate the canister therein with a clearance, the clearance defining a second annular space,

air inlet means at the lower end of the chamber communicating with the first and second annular spaces at the lower ends thereof, and

air outlet means at the upper end of the chamber communicating with the first and second annular spaces at the upper ends thereof.

2. A vault as claimed in claim 1 in which the liner comprises a number of apertures at the upper end thereof affording communication between the first and second annular spaces.

3. A dry storage vault as claimed in claim 1 or 2 in which the concrete body comprises cooling duct means arranged to cool the concrete body.

4. A vault as claimed in claim 2 or 3 in which the cooling duct means

communicates with the air inlet and air outlet means.

5. A vault as claimed in any of claims 1-4 in which the air outlet means comprises a first air outlet coupled to the first annular space and a second air outlet coupled to the second annular space.

6. A vault as claimed in claim 5 in which the second air outlet means comprises duct work arranged between the second annular space and the second air outlet vent, in which the duct work and vent comprise heat-resistant members.

7. A vault as claimed in claim 6 in which the heat-resistant members comprise metal members.

8. A vault as claimed in any preceding claim in which the vault comprises a plurality of precast concrete members.

9. A vault as claimed in claim 8 comprising baffle means arranged to cover at least one joint between abutting members to inhibit escape of radiation.

10. A vault as claimed in claim 8 in which the mating surfaces between abutting members are shaped to provide a baffle to inhibit escape of radiation.

11. A vault as claimed in any one of claims 8, 9, or 10 in which at least one joint

between abutting members is provided with a void arranged to be filled with concrete during assembly to secure the abutting members together.

12. A vault as claimed in any preceding claims comprising a plurality of chambers.

13. A method of constructing a vault as claimed in any preceding claims comprising the steps of

prefabricating individual concrete components, and;

assembling said prefabricated concrete components on-site.

14. A dry storage vault substantially as described with reference to or as illustrated in figures 1-9, figure 10 or figure 11 of the drawings.

15. A method of constructing a dry storage vault substantially as described.

The Patent Office

14

Application No: GB 9811538.9
Claims searched: 1-15

Examiner: Miss E.L.Rendle
Date of search: 25 August 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): B4Q; B8P (PV)

Int Cl (Ed.6): G21F 5/10, 7/015

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 1 456 860	(TECHNIGAZ) see figures 1 and 9.	-
A	US 5 564 498	(ROBATEL) SEE FIGURES.	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.